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Understanding the Global Navigation Satellite System: Functionality and Policy

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Part I: Background

This white paper provides a brief overview of the Global Navigation Satellite System (GNSS)[1], exploring the fundamental principles, operational mechanisms, and the policy context that governs its use. By examining both the technical aspects of GNSS and the associated policy framework, readers can develop a better understanding of the technology and its practical applications.

Part II: What is GNSS?

GNSS is a set of five satellite constellations owned by five countries, used to determine the location of devices such as smartphones, smart watches, and other devices that use location services. The system utilizes signals transmitted from multiple satellites to calculate precise position and provide navigation information.

Accessed as a whole, the GNSS constellations enhance availability, redundancy, and location accuracy. If one system or satellite fails, another constellation can fill in.

Source: GPS World

Part III: GNSS Constellations

GPS (Global Positioning System)

Developed by the United States Department of Defense (DoD), GPS initially served military navigation purposes. Operating in the L-Band (1-2 GHz), GPS utilizes rubidium clocks with an impressive accuracy of 5 parts in 10^11 (meaning they can keep time to within 0.0000000005 seconds over a period of one year). With 31 satellites orbiting the Earth twice a day, GPS is considered one of the most accurate satellite constellations, providing location accuracy within the range of 3.5-7.8 meters.

GLONASS (GLObalnaya NAvigatsionnaya Sputnikovaya Sistema)

GLONASS is a satellite navigation system developed by Russia. With 24 satellites in orbit, GLONASS offers positioning and timing services. The accuracy of GLONASS ranges from five to 10 meters. Assisted-GLONASS incorporates additional features for smartphones, utilizing cell towers to enhance location accuracy and making it a valuable backup system for GPS in urban areas with tall buildings.

Galileo

Developed by the European Union, Galileo is designed to be compatible with GPS and GLONASS, offering a robust global navigation system. With 30 satellites, Galileo employs hydrogen maser clocks, ensuring remarkable timing accuracy within 0.45 nanoseconds over a 12-hour period.

BeiDou

China's BeiDou system consists of two constellations: BeiDou-2 and BeiDou-3. BeiDou-2 focuses on providing coverage in the Asia-Pacific region and includes 10 satellites. BeiDou-3 aims to offer global coverage as an alternative to GPS, GLONASS, and Galileo, with a constellation of 35 satellites.

QZSS (Quasi-Zenith Satellite System)

Japan's Quasi-Zenith Satellite System employs a combination of geostationary and geosynchronous satellites. QZSS utilizes rubidium clocks and focuses on improving positioning accuracy and availability in the Asia-Oceania region.

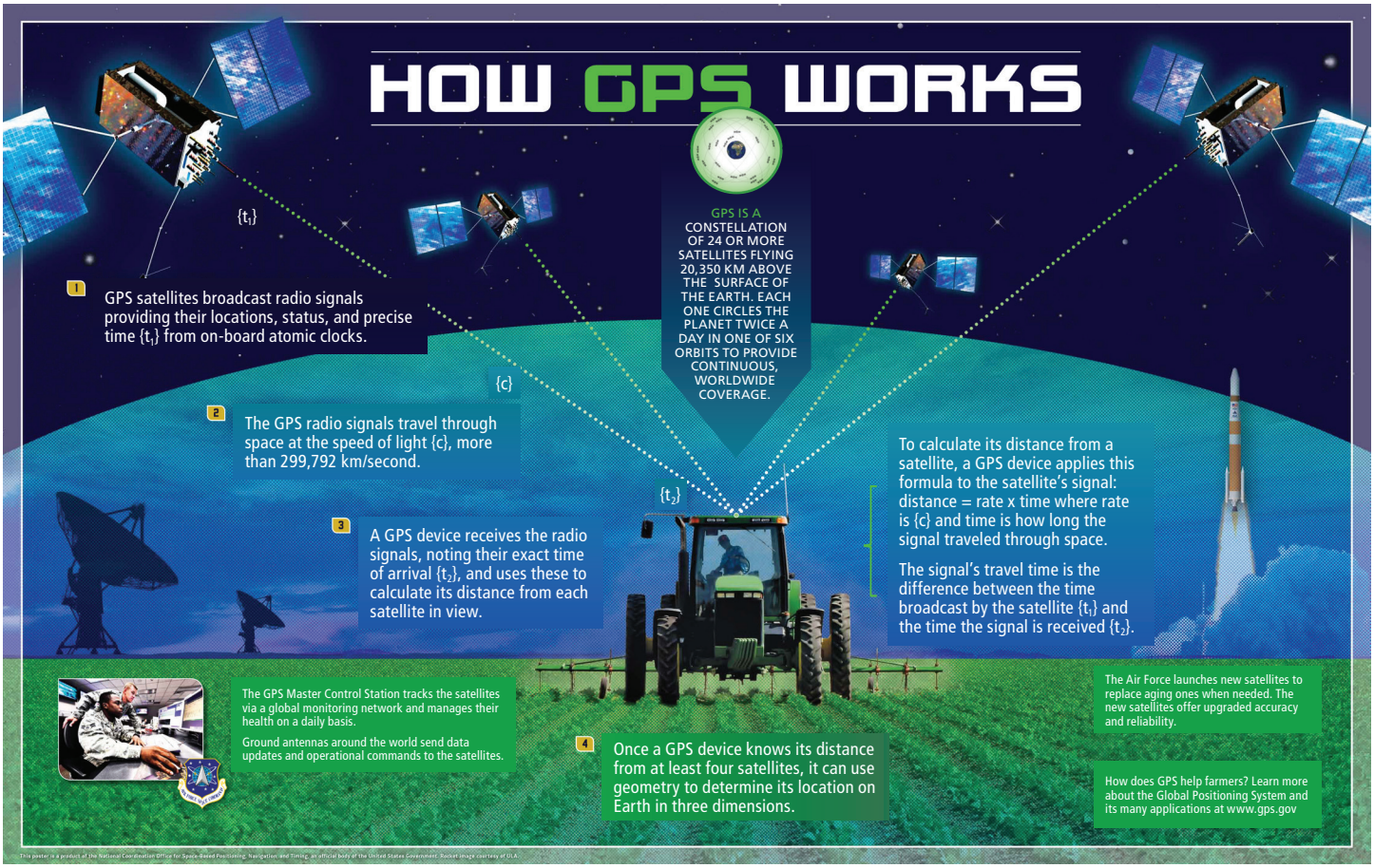
Part IV: Government Support for U.S. Businesses and Agencies

The U.S. government actively supports U.S. businesses in accessing and utilizing GNSS. Public-private partnerships are established to leverage the expertise and resources of private companies in developing innovative applications and services that rely on GNSS technology.

Funding, grants, regulatory support, export control reform, and business support programs facilitate access to GNSS signals, promote competitiveness in the global GNSS market, and enhance national security objectives.[3]

There are many U.S. companies that access GNSS, including:

- Aerospace companies, such as Boeing and Lockheed Martin, use GNSS for navigation and guidance systems in their aircraft and spacecraft.
- Automotive companies, such as Ford and General Motors, use GNSS in their cars for navigation and safety systems.
- Technology companies, such as Apple and Google, use GNSS in their smartphones and other devices for location-based services.
- Telecommunications companies, such as AT&T and Verizon, use GNSS for time synchronization and network planning.
- Utilities companies, such as electric and gas companies, use GNSS for asset tracking and outage management.



Source: GPS.gov

Part V: How It Works

All devices that use location navigation services operate on the same principle—the devices "listen" to radio frequency signals transmitted from the satellites at the speed of light and log the time the signals are transmitted and received.[2]

The location is then determined by trilateration of, at a minimum, three satellite signals and the respective times their transmissions are received by the device. This geometric calculation of the distance the device is from each satellite results in a determination of the device's location.

Devices do not transmit any information to the satellite and the satellites do not know which devices are receiving signals or where the devices are located, similar to how radio transmitters and radios work.

Part VI: GNSS Functionality

- **Satellite Constellation:** GNSS is a constellation of satellites orbiting the Earth at precise locations. These satellites continuously emit signals that include exact timing information and their own orbital parameters.
- **Signal Reception:** GNSS receivers, found in various devices such as smartphones, vehicles, and specialized equipment, capture signals transmitted by the GNSS satellites. The receiver's primary task is to receive and process these signals.
- **Trilateration:** By analyzing the time, it takes for signals to travel from satellites to the receiver, the GNSS receiver can calculate the distance between each satellite and itself.
- **Position Calculation:** Using trilateration, the GNSS receiver can determine its precise three-dimensional position by intersecting the distances from at least four satellites. The receiver compares the known satellite positions with the measured signal travel times to calculate its own location accurately.

- **Navigation and Timing:** Once the GNSS receiver has determined its precise position, it can provide users with accurate navigation information such as speed, direction, and distance to a desired location. GNSS also offers highly accurate timing synchronization, allowing for precise timekeeping and synchronization of clocks.

Part VII: Data Privacy and GNSS

It is important to note that GNSS technology itself does not collect or transmit personal data. GNSS receivers, including those in smartphones and other devices, rely solely on signals emitted by the satellites to determine position and provide navigation information. Satellite technology does not have the capability to store or retrieve personal data.

Applications that use location services relying on GNSS have their own privacy policies. Users of such applications should understand those privacy policies to ensure their service providers are following data protection and privacy regulations.

Part VIII: U.S. National Space Policy

Global Navigation Satellite System provides users with precise positioning, navigation, and timing capabilities. By understanding the functionality of GNSS and its policy context, individuals, businesses, and government agencies can harness the benefits of this technology, drive innovation, and contribute to global positioning and navigation advancements.

The policy framework surrounding GNSS emphasizes international cooperation, security, and responsible space practices to ensure the availability, reliability, and interoperability of GNSS services on a global scale.[4]

That being said, the U.S. government has committed to ensuring that GNSS is available to everyone, regardless of their location or nationality. They also want to make sure that GNSS is secure and used for mutually beneficial purposes. The end goal is the ability for all GNSS systems from different countries to work together seamlessly.

Part IX: Conclusion

The future of GNSS is promising, as evidenced by its critical role in serving billions of people worldwide. GNSS provides essential precise positioning, navigation, and timing capabilities for various applications, including transportation, telecommunications, critical infrastructure, and community corrections.

Furthermore, the U.S. government's policy framework promotes international cooperation, security, and responsible space practices. With the development of GNSS constellations by more countries, the availability and reliability of GNSS services will continue to improve, leading to innovative applications that simplify our lives. Additionally, the utilization of multiple data sources enhances system redundancy, ensuring uninterrupted operation in the face of component failures or disruptions.

Sources

[1] "Global Navigation Satellite Systems (GNSS)" by European GNSS Agency (GSA)
[2] "How GPS Works" by GPS.gov
[3] "United States National Space Policy"
[4] "Overview of Global Navigation Satellite Systems" by United Nations Office for Outer Space Affairs (UNOOSA)